

CLAIMS:

1. An integrated surgical system for use in an orthopaedic operating room to enable a surgeon to carry out a computer aided surgical procedure on a subject, the integrated
5 surgical system comprising:
 - a subject support on which the subject can be positioned;
 - a wireless magnetic tracking system, the tracking system generating a magnetic field defining a working volume of the tracking system, the subject support being located at least partially within the working volume, and the tracking system including a tracking
10 control system configured to track the position of a marker detectable by the tracking system within the working volume and generate a signal indicative of the position of the marker within a reference frame of the tracking system;
 - a registration system configured to register the position of the body part of the subject with an image of the body part of the subject within the reference frame of the
15 tracking system;
 - at least a first display device configured to display a registered image of the body part of the subject and at least an image representative of a trackable implant during the computer aided surgical procedure;
 - a control system configured to integrate the functionalities of a plurality of the
20 parts of the surgical system; and
 - a surgeon interface operable by the surgeon to control operation of the plurality of parts of the integrated surgical system.
2. The system of claim 1, and further comprising a further wireless tracking system,
25 the further wireless tracking system being an infrared wireless tracking system and being in communication with the control system and configured to generate a signal indicative of the position of a tracked element in the reference frame of the further wireless tracking system.
3. The system as claimed in claim 1, wherein the first display device is a touch
30 sensitive display and comprises a part of the surgeon interface.

4. The system as claimed in any of claims 1 to 3, and the surgeon interface including an orientation sensitive device operable by a surgeon to enter control commands.
- 5 5. The system as claimed in any of claims 1 to 4, and the surgeon interface including a heads up display wearable by the surgeon and configured to display at least a one of the images selected from the group comprising: a captured image of the body part; an image of a model of the body part; a registered image of the body part; a video image of the body part; a representation of an implant; a representation of an instrument; an
10 indication of the planned position of an implant, instrument or incision; and any combination of the preceding.
6. The system as claimed in any of claims 1 to 5, and further comprising a wall display unit, the wall display unit being configured to provide a plurality of image regions,
15 each image region being capable of displaying a different image.
7. The system as claimed in claim 6, wherein the different images are selected from the group comprising: a captured image of the body part; an image of a model of the body part; a registered image of the body part; a video image of the body part; a representation
20 of an implant; a representation of an instrument; an indication of the planned position of an implant, instrument or incision; and any combination of the preceding.
8. The system as claimed in any preceding claim, and wherein the system further comprises a surgical site display device, the surgical site display device including an
25 image display portion and a support, and wherein the image display portion is positionable over the surgical site of the patient in use.
9. The system as claimed in claim 8, and wherein the surgical site display device includes an image capturing device having a field of view including the surgical site and
30 generating a surgical site image, and wherein the surgical site image is displayed in the image display portion.

10. The system as claimed in claim 9, wherein the surgical site image is a real time video image of the surgical site.

11. The system as claimed in claim 9 or 10, wherein a further image is overlayed on
5 the surgical site image and the further image and the surgical site image are displayed in the image display portion at the same time, and wherein the further image is selected from the group comprising: a captured image of the body part; an image of a model of the body part; a registered image of the body part; a video image of the body part; a representation of an implant; a representation of an instrument; an indication of the planned position of
10 an implant, instrument or incision; and any combination of the preceding.

12. The system as claimed in any preceding claim, and further comprising an image capturing device which captures real time video images, and wherein the real time video images are displayed in real time on at least one display device of the system.

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13. The system as claimed in claim 12, and further comprising a surgical light, the surgical light being suspended and being movable to different positions and orientations with respect to the operating table, and wherein the image capturing device is provided as a part of the surgical light.

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14. The system as claimed in any preceding claim and further comprising an image storage device storing a plurality of captured images of the body part of the subject, the images of the body part being selected from the group comprising: X-ray images; CT scan images; and X-ray fluoro images.

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15. The system as claimed in any preceding claim and further comprising a body part model storage device, storing a plurality of generic 3-d models of different body parts.

16. The system as claimed in any preceding claim and further comprising an implant
30 image storage device storing 3d images of a plurality of implants useable in the computer aided surgical procedure.

17. The system as claimed in any preceding claim and further comprising an instrument image storage device storing 3d images of a plurality of instruments useable in the computer aided surgical procedure.

5 18. The system as claimed in any preceding claim, and wherein the registration system is an X-ray or X-ray fluoroscopy registration system.

19. The system as claimed in claim 18, wherein the registration system is configured to capture at least a first image and a second image of the body part from different
10 directions with the patient on the operating table.

20. The system as claimed in claim 19, wherein the registration system includes a first x-ray source and a second x-ray source, a first detector positioned to capture the first image of the body part resulting from the first x-ray source and a second detector
15 positioned to capture the second image of the body part resulting from the second x-ray source.

21. The system as claimed in claim 20, wherein the first detector and the second detector are positioned above the subject support and the first x-ray source and the second
20 x-ray source are positioned below the subject support.

22. The system as claimed in any of claims 19 to 21, wherein the control system includes computer program instruction executable:

25 to generate a 3d image of the body part from the first image and second image;
to determine the position of the body part in the reference frame of the tracking system; and

to register the 3d image of the body part with the position of the body part in the reference frame of the tracking system.

30 23. The system as claimed in any preceding claim, wherein the tracking system includes a magnetic field generating subsystem and wherein the position of the magnetic

field generating subsystem or subject support is movable so as to change the position or orientation of the working volume relative to the subject support.

24. The system as claimed in claim 23, wherein a part of the subject support is
5 movable and/or a part of the magnetic field generating subsystem is movable.

25. The system as claimed in claim 21, wherein the first x-ray source and the second x-ray source are provided in a floor on which the subject support is located.

10 26. The system as claimed in any preceding claim and including a video mixing and control subsystem which controls the display of images on a plurality of different image display parts of the system.

27. The system as claimed in any preceding claim, wherein the control system
15 includes computer program instructions providing an orthopaedic surgery workflow program.

28. The system as claimed in claim 27, wherein the control system includes computer program instructions providing an orthopaedic implantation planning program.
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29. The system as claimed in claim 28, wherein the control system includes computer program instructions providing an orthopaedic image guided surgery program for implementing the orthopaedic procedure at least partially planned by the orthopaedic planning program.
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30. The system as claimed in any of claims 27 to 29, and wherein the tracking system passes data indicating the identity of a marker being tracked by the tracking system to the control system, and wherein the control system determines whether the marker is associated with the position of a bone, an implant or an instrument.
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31. The system as claimed in any preceding claim, and further comprising at least one marker wirelessly trackable by the tracking system.

32. The system as claimed in claim 31, wherein the marker is attached to an implant.
33. The system as claimed in claim 31, wherein the marker is attached to an instrument.
- 5 34. The system as claimed in claim 31, and wherein the marker has a housing including a bone anchor for retaining the marker within the bone of the subject and wherein the marker is hermetically sealed in the housing.
- 10 35. The system as claimed in claim 34, and wherein the housing is configured to be percutaneously implantable within the bone of a subject.
36. The system as claimed in any preceding claim, and further including a prosthetic joint, the prosthetic joint comprising a first orthopaedic implant bearing a first marker
15 wirelessly trackable by the tracking system and a second orthopaedic implant bearing a second marker wirelessly trackable by the tracking system.
37. The system as claimed in claim 36, wherein the prosthetic joint is a prosthetic knee joint, the first orthopaedic implant is a femoral component and the second
20 orthopaedic component is a tibial component, and the femoral component includes a locating pin which in use is located within the femur and the first marker is located at least partially within the locating pin, and the tibial component includes a keel which in use is located within the tibia and the second marker is located at least partially within the keel.
- 25 38. The system as claimed in claim 36, wherein the prosthetic joint is a prosthetic hip joint, the first orthopaedic implant is an acetabular component and the second orthopaedic component is a femoral component, and the acetabular component is a cup and the first marker is located within a wall of the cup at an apex of the cup, and the femoral
30 component includes a body and the second marker is located at least partially within the body.

39. The system as claimed in any of claims 1 to 38, wherein the system includes at least three markers wirelessly trackable by the wireless magnetic tracking system, and wherein:

5 a first of the three markers is configured to be powered by RF induction and is implantable in the bone of the subject;

a second of the three markers is configured to be powered by RF induction and is attachable to an orthopaedic implant for implanting in the body of the subject; and

10 a third of the three markers has a battery and is attachable to an instrument for use in the surgical procedure of implanting the orthopaedic implant in the body of the subject.

39. A dummy body part for use in training a surgeon to carry out an orthopaedic surgical procedure on a surgical site, the dummy body comprising:

15 an outer layer of a first material which mimics skin;
an inner volume of a second material within the outer layer which mimics interior body tissues; and

20 a three dimensional formation of a third material which mimics bone located within the inner volume, wherein the outer layer, inner volume and formation are configured to correspond to a joint of a human body.

40. The dummy body part as claimed in claim 39, wherein the dummy body part has a first three dimensional formation corresponding to a knee joint and a second three dimensional formation corresponding to a hip joint.

25 41. The dummy body part as claimed in claim 39 or 40, wherein the first material is a polyurethane elastomer, the second material is a polyurethane elastomer and the third material is a solid foam.

30 42. A method for operating an integrated surgical system to enable a surgeon to carry out a computer aided surgical procedure on a body part of a subject positioned on a subject support in an operating room, the method comprising:

- determining the position of at least a first marker being wirelessly tracked by a wireless magnetic tracking system which generates a magnetic field defining a working volume of the tracking system within which the subject support is at least partially located, the position of the marker being within a reference frame of the tracking system;
- 5 registering the position of the body part of the subject with an image of the body part of the subject within the reference frame of the tracking system;
- displaying a registered image of the body part of the subject and at least an image representative of an implant bearing the marker at a current position of the implant relative to the body part on at least a first display device during the computer aided
- 10 surgical procedure; and
- receiving a command from a surgeon interface operable by the surgeon and controlling operation of at least a one of the plurality of parts of the integrated surgical system responsive to the command.
- 15 43. The method of claim 42, and further comprising determining the position of at least a second marker being wirelessly tracked by an infrared wireless tracking system, the position of the second marker being within a reference frame of the infrared wireless tracking system.
- 20 44. The method of claim 43, and further comprising determining the position of the second marker in the reference frame of the wireless magnetic tracking system.
45. The method of any of claims 42 to 44 and further comprising determining the position of an element to which the marker is attached in the reference frame of the
- 25 magnetic wireless tracking system.
46. The method as claimed in any of claims 42 to 45 and further comprising:
 generating an image for display on a heads up display wearable by the surgeon;
and
- 30 supplying the image to the heads up display, wherein the image is selected from the group comprising: a captured image of the body part; an image of a model of the body part; a registered image of the body part; a video image of the body part; a representation

of an implant; a representation of an instrument; an indication of the planned position of an implant, instrument or incision; and any combination of the preceding.

47. The method as claimed in any of claims 42 to 46, and further comprising:

5 generating a plurality of different images for display on a wall display unit configured to provide a plurality of image regions, each image region being capable of displaying a different image; and

supplying a one of the plurality of images for display in each of the image regions.

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48. The method as claimed in claim 47, wherein the different images are selected from the group comprising: a captured image of the body part; an image of a model of the body part; a registered image of the body part; a video image of the body part; a representation of an implant; a representation of an instrument; an indication of the
15 planned position of an implant, instrument or incision; and any combination of the preceding.

49. The method as claimed in any of claims 42 to 47, and further comprising:
capturing a surgical site image of a surgical site; and

20 supplying the surgical site image to a display device positionable over the surgical site of the patient in use.

50. The method as claimed in claim 49, wherein the surgical site image is a real time video image of the surgical site.

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51. The method as claimed in claim 49 or 50, and further comprising:

registering a further image with the position of the surgical site;

and overlaid the further image on the surgical site image, wherein the further image is selected from the group comprising: a captured image of the body part; an image
30 of a model of the body part; a registered image of the body part; a video image of the body part; a representation of an implant; a representation of an instrument; an indication of the

planned position of an implant, instrument or incision; and any combination of the preceding.

52. The method of any of claims 42 to 51 and further comprising:
5 capturing real time video images of a surgical site; and
supplying the real time video images for display in real time on at least one display device of the system.

53. The method as claimed in any of claims 42 to 52 and further comprising:
10 retrieving an image from an image storage device which stores a plurality of captured images of the body part of the subject, the images of the body part being selected from the group comprising: X-ray images; CT scan images; and X-ray fluoro images.

54. The method as claimed in any of claims 42 to 53 and further comprising:
15 selecting a one of a plurality of generic 3d models of different body parts stored in a storage device;
morphing the selected one of the plurality of generic 3d models to more closely match the body part of the subject; and
generating an image derived from the morphed generic 3d model.

20 55. The method as claimed in any of claims 42 to 54 and further comprising:
selecting a one of a plurality of stored 3d images of a plurality of implants useable in the computer aided surgical procedure;
determining the current orientation and position of an implant corresponding to
25 the selected implant;
generating an image from the selected 3d image of the implant corresponding to a surgeon's view of the implant for the current orientation of the implant; and
displaying the image at the current position of the implant.

30 56. The method as claimed in any of claims 42 to 55 and further comprising:
selecting a one of a plurality of stored 3d images of a plurality of instruments useable in the computer aided surgical procedure;

determining the current orientation and position of an instrument corresponding to the selected implant;

generating an image from the selected 3d image of the instrument corresponding to a surgeon's view of the instrument for the current orientation of the instrument; and

5 displaying the image at the current position of the instrument.

57. The method as claimed in any of claims 42 to 56, and further comprising:

capturing a first x-ray or x-ray fluoroscopy image of the body part for a first direction and a second x-ray or x-ray fluoroscopy image of the body part for a second

10 direction, different to the first direction;

generating a 3d image of the body part from the first image and second image;

determining the position of the body part in the reference frame of the tracking system; and

15 registering the 3d image of the body part with the position of the body part in the reference frame of the tracking system.

58. The method as claimed in any of claims 42 to 57 and further comprising controlling images from different sources and displaying images from different sources on different image display parts of the system.

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59. The method as claimed in any of claims 42 to 58, and further comprising:

displaying a user interface for an orthopaedic surgery workflow program; and receiving and processing commands entered via the user interface.

25 60. The method as claimed in any of claims 42 to 59, and further comprising:

displaying a user interface for an orthopaedic implantation planning program; receiving and processing orthopaedic planning commands entered via the user

interface; and

saving at least a part of a surgical plan.

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61. The method as claimed in claim 60, and further comprising:

displaying a user interface for an orthopaedic image guided surgery program; and

receiving and processing commands entered via the user interface to control the image guided surgery procedure.

62. The method as claimed in claim 61, and further comprising generating and
5 displaying images to guide the surgeon to carry out surgical steps at least partially planned by the orthopaedic planning program.

63. The method as claimed in any of claims 42 to 62, and further comprising:
determining the identity of each of a plurality of markers being tracked by the
10 tracking system; and
determining the nature of an element with which the marker is associated.

64. The method as claimed in claim 63 wherein the nature of the element is selected
from the group comprising: a bone; an implant; and an instrument.
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65. The method as claimed in any of claims 42 to 64, and further comprising
determining the current position of an instrument in the reference frame of the tracking
system.

20 66. The method as claimed in any of claims 42 to 65, and further comprising
determining the current position of a bone in the reference frame of the tracking system.

67. The method as claimed in any of claims 42 to 66, and further comprising:
determining the position in the reference frame of the tracking system of a first
25 orthopaedic implant bearing a first marker wirelessly trackable by the tracking system;
and

determining the position in the reference frame of the tracking system of a
second orthopaedic implant bearing a second marker wirelessly trackable by the tracking
system.

68. The method as claimed in claim 67, wherein the first orthopaedic implant is a femoral component of a prosthetic knee joint and the second orthopaedic component is a tibial component of a prosthetic knee joint.

5 69. The method as claimed in claim 67, wherein the first orthopaedic implant is an acetabular component of a hip joint and the second orthopaedic component is a femoral component of a hip joint.

70. Computer program code executable by a data processing device to provide the
10 method of any of claims 42 to 69.

71. A computer readable medium bearing computer program code as claimed in claim 70.

15 72. A wirelessly trackable prosthetic joint for implanting using an image guided surgical procedure, the prosthetic joint comprising:
a first component bearing a first wirelessly trackable marker; and
a second component bearing a second wirelessly trackable marker, wherein the first wirelessly trackable marker and the second wirelessly trackable marker are each
20 hermetically sealed.

73. The prosthetic joint as claimed in claim 72, wherein the joint is a uni-condyle prosthetic knee, and wherein the first component is a femoral component having a femur engaging surface and a bearing surface corresponding to a single condyle of the femur,
25 and the second component is a tibial component having a tibia engaging surface and a bearing on an opposed side, wherein the bearing is configured to engage with a single condyle bearing surface only of the femoral component as the prosthetic knee is articulated.

30 74. The prosthetic joint as claimed 73, wherein the femoral component includes a location pin extending from the femur engaging surface, the location pin having a cavity therein in which the marker is at least partially located.

75. The prosthetic joint as claimed 74, wherein the femoral component is configured with at least a first sensor coil of the marker aligned with a longitudinal axis of the femur.

76. The prosthetic joint as claimed in any of claims 72 to 75, wherein the tibial
5 component includes a keel or anchor part for engaging in the tibia in use and wherein the marker is located at least partially in the keel or anchor part.

77. The prosthetic joint as claimed 76, wherein the tibial component is configured with at least a first sensor coil of the marker aligned with an anterior-posterior direction of
10 the tibia.

78. The prosthetic joint as claimed in claim 72, wherein the joint is a hip joint, the first component is an acetabular component and the second component is a femoral component.

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79. The prosthetic joint as claimed in claim 78, wherein the first marker comprises a housing defining a cavity and a marker located within the cavity.

80. The prosthetic joint as claimed in claim 79, wherein the acetabular component
20 has a wall and the acetabular marker is located within the wall of the acetabular component.

81. The prosthetic joint as claimed in claim 80, wherein the housing has a convex outer surface and a concave inner surface, the acetabular component has a convex outer
25 surface and a concave inner surface and wherein the outer surface of the housing smoothly continues the outer surface of the acetabular component and the inner surface of the housing smoothly continues the inner surface of the acetabular component.

82. The prosthetic joint as claimed in any of claims 78 to 81, wherein the femoral
30 component defines a cavity and the second marker is located at least partially in the cavity in the femoral component.

83. A kit of parts for use in a computer aided orthopaedic surgical procedure, comprising:

a first percutaneously implantable marker for implanting in a first bone associated with a joint to be replaced;

5 a second percutaneously implantable marker for implanting in a second bone associated with the joint to be replaced; and

the prosthetic joint as claimed in any of claims 72 to 82.

84. The kit as claimed in claim 83 and further comprising an instrument assembly for
10 injecting the first and second markers through the skin of the patient so as to implant the markers in the bones of the patients.

85. A computer implemented method for carrying out an orthopaedic surgical procedure including implanting a first orthopaedic implant bearing a first marker
15 magnetically wirelessly trackable by a tracking system and a second orthopaedic implant bearing a second marker magnetically wirelessly trackable by the tracking system in a body of a subject, and wherein the tracking system has a reference frame, the method comprising:

creating a surgical plan defining the intended implantation positions for the first
20 and second orthopaedic implants;

registering an image of a part of the body of the subject with the position of the part of the body of the subject in the reference frame of the tracking system whereby the surgical plan is registered with the tracking system;

determining current positions of the first and second orthopaedic implants within
25 the reference frame of the tracking system; and

displaying a first image representing the part of the body of the patient, a second image representing the real time, current position of the first orthopaedic implant and/or a third image representing the real time, current position of the second orthopaedic implant and displaying an indication of the planned positions of the first and second orthopaedic
30 implants relative to the body part derived from the surgical plan.

86. A method for carrying out an orthopaedic computer aided surgery procedure on a body of a subject in an operating room, the method comprising:

planning the intended position of a first orthopaedic implant wirelessly magnetically trackable by a tracking system having a reference frame;

5 registering a part of the body of the subject in the operating room;

using an image guided surgery system to determine an implantation position of the first orthopaedic implant in the part of the body; and

implanting the orthopaedic implant at the implantation position.

10 87. The method as claimed in claim 86, and further comprising percutaneously implanting at least a first sensor wirelessly magnetically trackable by the tracking system in a bone of the part of the body.

88. The method as claimed in claim 87, wherein the first sensor is implanted prior to
15 locating the body in the operating room.

89. The method as claimed in claim 87, wherein the first sensor is implanted with the body in the operating room.

20 90. The method as claimed in claim 89, and wherein the first sensor is implanted prior to planning the intended position of the first orthopaedic implant.

91. The method as claimed in any of claims 86 to 90, and wherein registering a part of the body occurs before planning the intended position of the first orthopaedic implant.
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92. The method as claimed in any of claims 86 to 91 and further comprising:
taking first and second x-ray, or x-ray fluoroscopic, images of the part in the operating room from different directions; and
planning the intended position of the first orthopaedic implant using a 3d model
30 of the body part derived from the first and second images.

93. The method as claimed in claim 92, wherein the first and second x-ray, or x-ray fluoroscopic, images of the part are taken without moving the patient in the operating room.

5 94. The method as claimed in any of claims 86 to 93 and further comprising visually assessing the performance of the implanted first orthopaedic implant in the operating room by viewing a real time representation of the position of the implant and/or the part of the body immediately after implantation and before closing the surgical wound.

10 95. The method as claimed in any of claims 86 to 94 and further comprising percutaneously removing a marker wirelessly magnetically trackable by the tracking system from within a bone of the body part.